Jet Propulsion Laboratory
California Institute of Technology

The Cuprite Project: Mineral Unmixing in the Longwave Infrared

Kerry Cawse-Nicholson, Simon Hook, Glynn Hulley

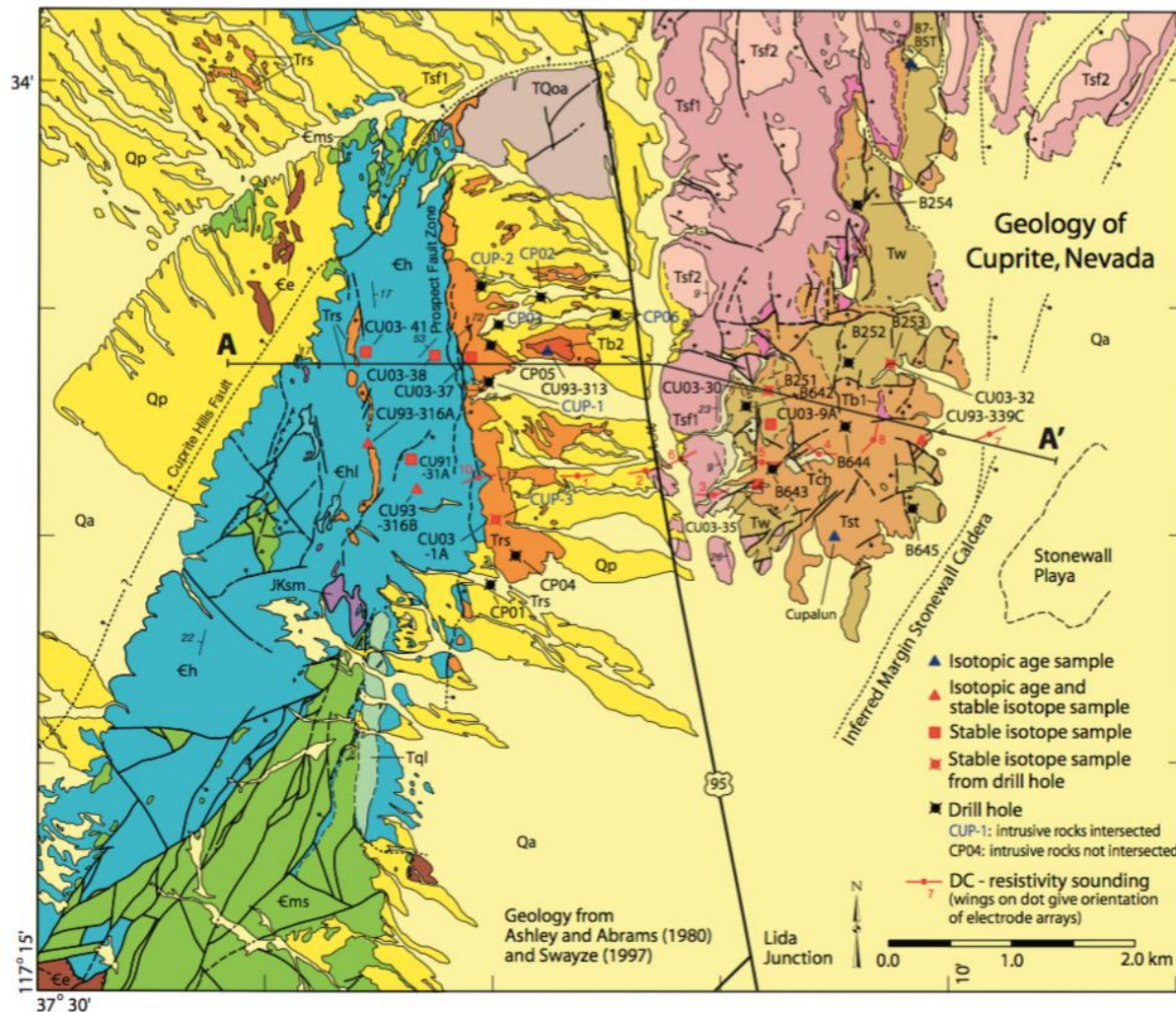*Jet Propulsion Laboratory, California Institute of Technology*

Mineral detection ranges

	Structure	Mineral Group	Example	VNIR Response	SWIR Response	LWIR Response
Silicates	Inosilicates	Amphibole	Actinolite	Non-Diagnostic	Good	Moderate
		Pyroxene	Diopside	Good	Moderate	Good
	Cyclosilicates	Tourmaline	Elbaite	Non-Diagnostic	Good	Moderate
	Nesosilicates	Garnet	Grossular	Moderate	Non-Diagnostic	Good
		Olivine	Forsterite	Good	Non-Diagnostic	Good
	Sorosilicates	Epidote	Epidote	Non-Diagnostic	Good	Moderate
	Phyllosilicates	Mica	Muscovite	Non-Diagnostic	Good	Moderate
		Chlorite	Clinochlore	Non-Diagnostic	Good	Moderate
		Clay Minerals	Illite	Non-Diagnostic	Good	Moderate
			Kaolinite	Non-Diagnostic	Good	Moderate
	Tectosilicates	Feldspar	Orthoclase	Non-Diagnostic	Non-Diagnostic	Good
			Albite	Non-Diagnostic	Non-Diagnostic	Good
		Silica	Quartz	Non-Diagnostic	Non-Diagnostic	Good
Non-Silicates	Carbonates	Calcite	Calcite	Non-Diagnostic	Moderate	Good
		Dolomite	Dolomite	Non-Diagnostic	Moderate	Good
	Hydroxides		Gibbsite	Non-Diagnostic	Good	Moderate
	Sulphates	Alunite	Alunite	Moderate	Good	Moderate
			Gypsum	Non-Diagnostic	Good	Good
	Borates		Borax	Non-Diagnostic	Moderate	Uncertain
	Halides	Chlorides	Halite	Non-Diagnostic	Uncertain	Uncertain
	Phosphates	Apatite	Apatite	Moderate	Non-Diagnostic	Good
	Hydrocarbons		Bitumen	Uncertain	Moderate	Uncertain
	Oxides	Hematite	Hematite	Good	Non-Diagnostic	Non-Diagnostic
		Spinel	Chromite	Non-Diagnostic	Non-Diagnostic	Non-Diagnostic
	Sulphides		Pyrite	Non-Diagnostic	Non-Diagnostic	Non-Diagnostic

Source: TerraCore Africa, with permission.

Cuprite

Geology of Cuprite, Nevada

Geology from Ashley and Abrams (1980) and Swayze (1997)

HyTES

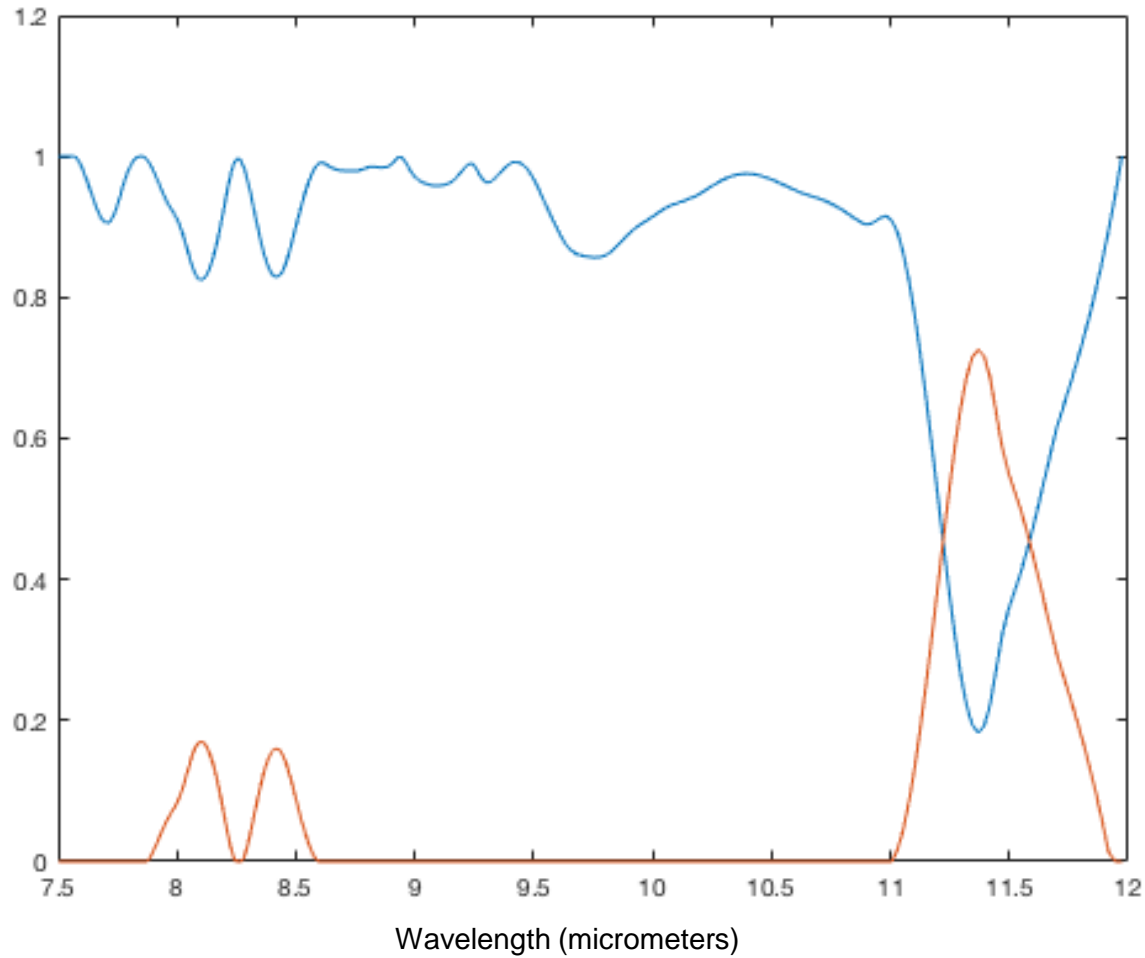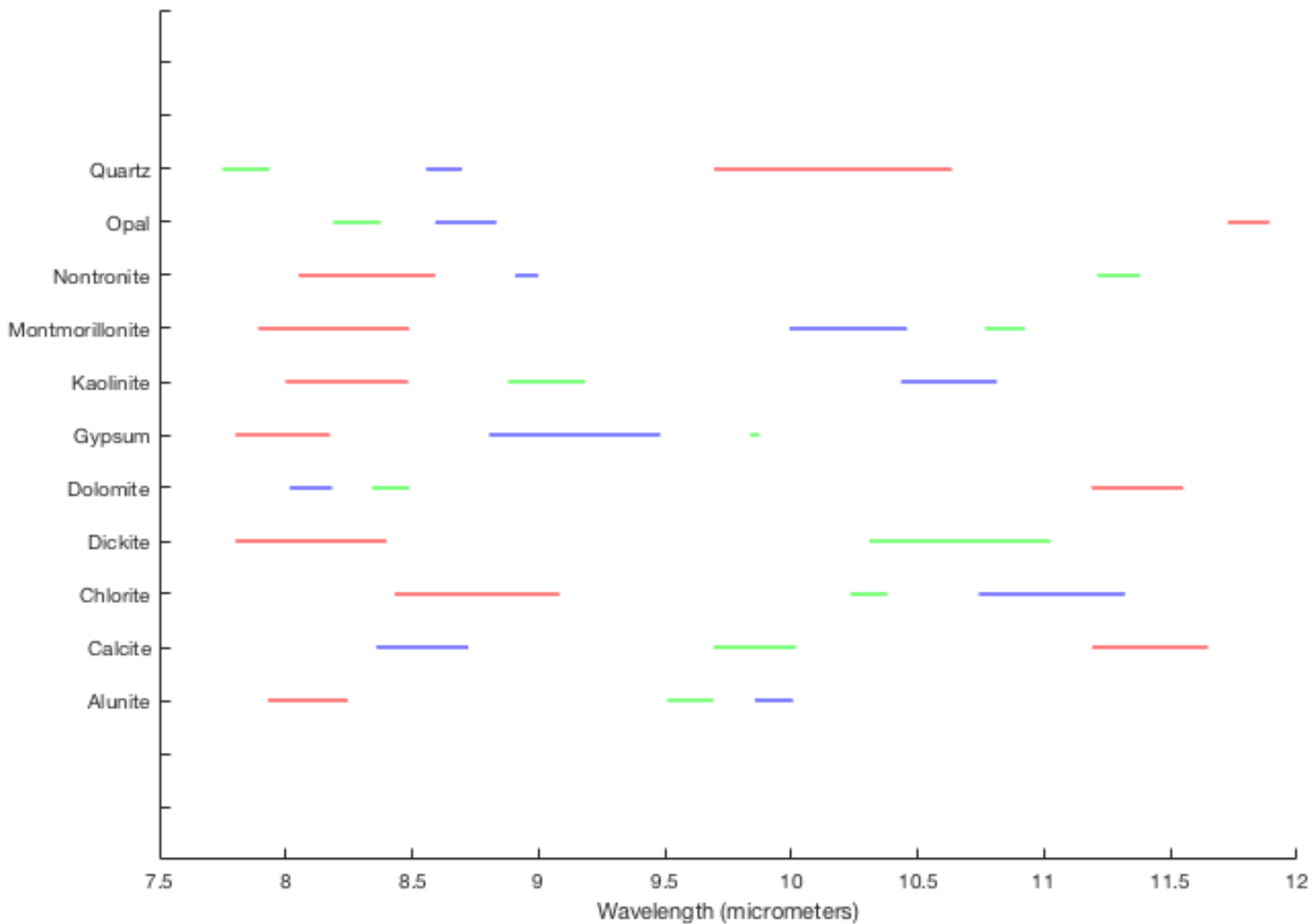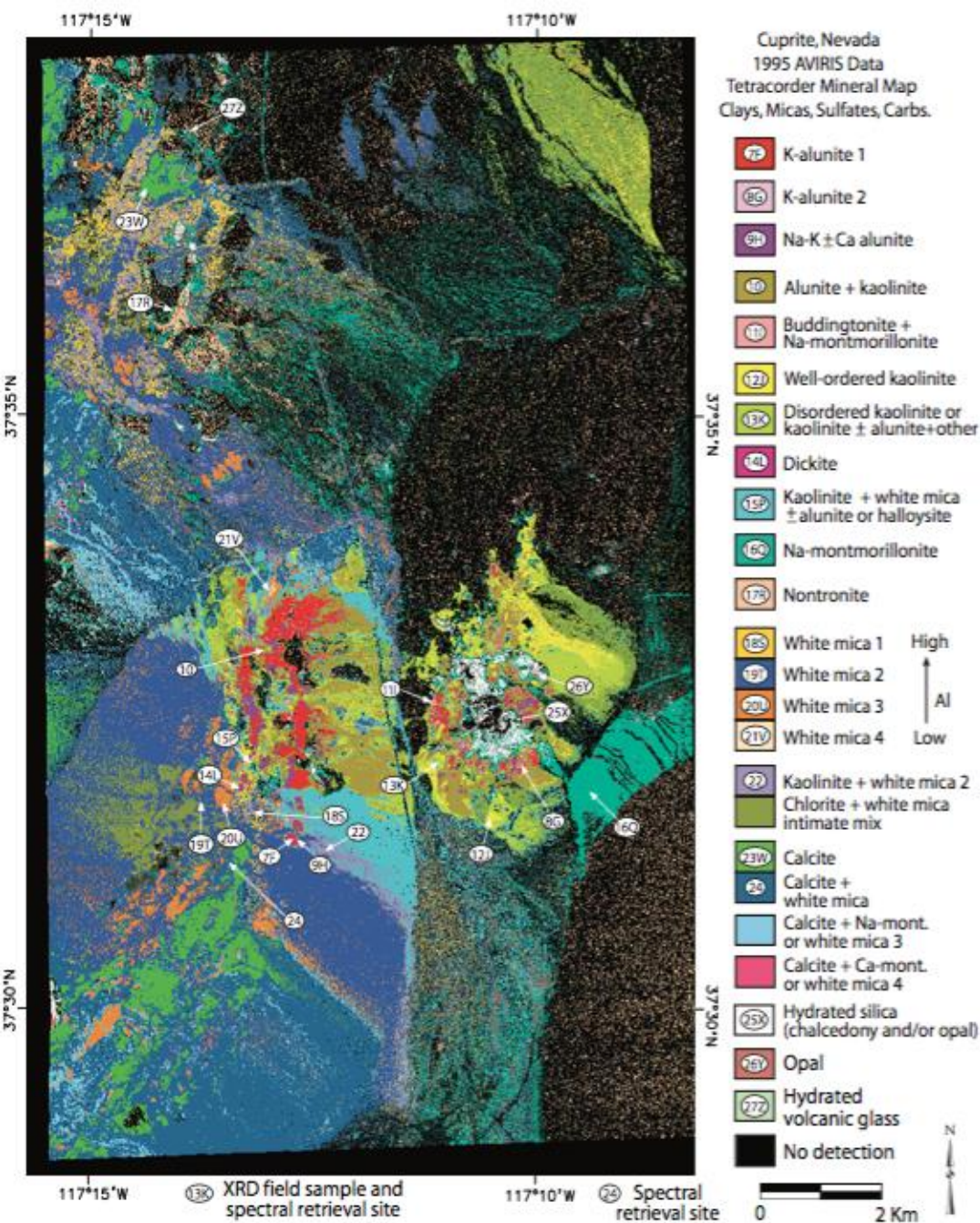| Instrument Characteristic	HyTES
Mass (Scanhead)	12kg
Power	400W
Volume	1m x 0.5m (cylinder)
Number of pixels x track	512
Number of bands	256
Spectral Range	7.5 - 12 μm
Spectral Sampling Interval	4.5μm/256, i.e. 17 nm
Frame speed	35 or 22 fps
Integration time (1 scanline)	28 or 45 ms
Total Field of View	50 degrees
Calibration (preflight)	Full Aperature Blackbody
Detector Temperature	40K
Spectrometer Temperature	100K
Slit Length and Width	20 mm x 39 μm
IFOV	1.7066
Pixel Size/Swath at 2,000 m flight altitude	3.41m/1868.33m
Pixel Size/Swath at 20,000 m flight altitude	34.13m/18683.31m

Mineral features

Chlorite

Chlorite
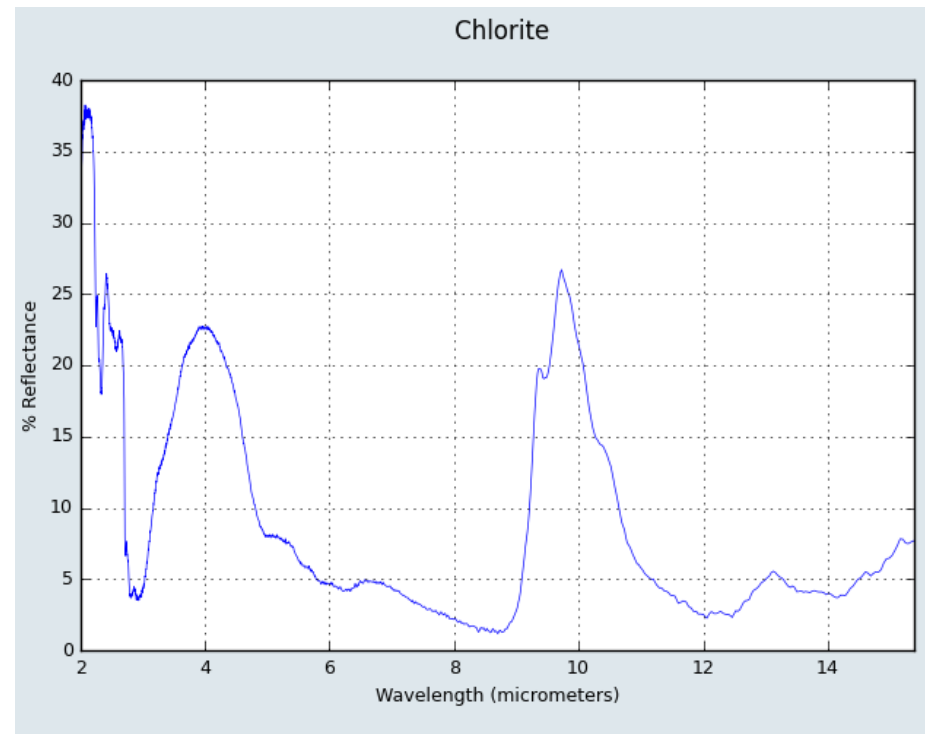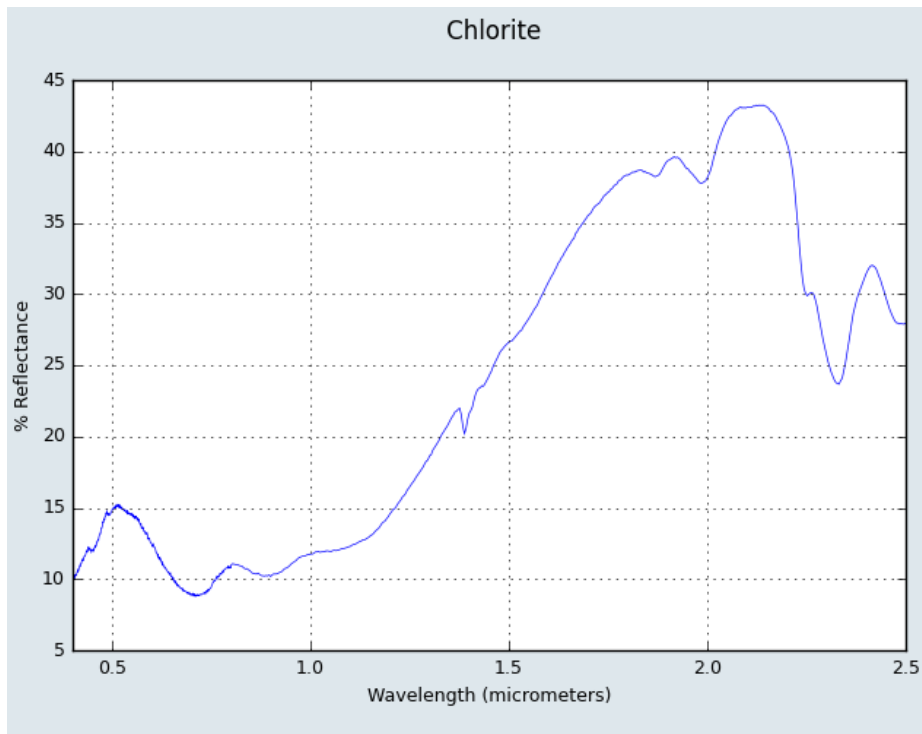
Mineral features

Mineral features

Wavelength (micrometers)

Mineral features

Cuprite, Nevada
1995 AVIRIS Data
Tetracorder Mineral Map
Clays, Micas, Sulfates, Carbs.

- (7S) K-alunite 1
- (8G) K-alunite 2
- (9H) Na-K ± Ca alunite
- (10) Alunite + kaolinite
- (11) Buddingtonite + Na-montmorillonite
- (12J) Well-ordered kaolinite
- (13K) Disordered kaolinite or kaolinite ± alunite+other
- (14L) Dickite
- (15P) Kaolinite + white mica ± alunite or halloysite
- (16Q) Na-montmorillonite
- (17R) Nontronite
- (18S) White mica 1 — High
- (19T) White mica 2
- (20U) White mica 3 — Al
- (21V) White mica 4 — Low
- (22) Kaolinite + white mica 2
  Chlorite + white mica intimate mix
- (23W) Calcite
- (24) Calcite + white mica
- Calcite + Na-mont. or white mica 3
- Calcite + Ca-mont. or white mica 4
- (25X) Hydrated silica (chalcedony and/or opal)
- (26Y) Opal
- (27Z) Hydrated volcanic glass
- No detection

(13K) XRD field sample and spectral retrieval site
(24) Spectral retrieval site

0 — 2 Km

N

Tetracorder

- Tetracorder (Clark, Swayze and Livo, et al. 2003), is perhaps the best-known rule-based mineral mapping system.
- The algorithm first removes the continuum of the spectrum.
- Next, diagnostic wavelength ranges (the range containing local minima unique to a particular mineral type) are used along with an extensive library of minerals to identify mineral classes.
- A number of other rules avoid false matches, including a comparison at both reflectance and continuum-removed level.
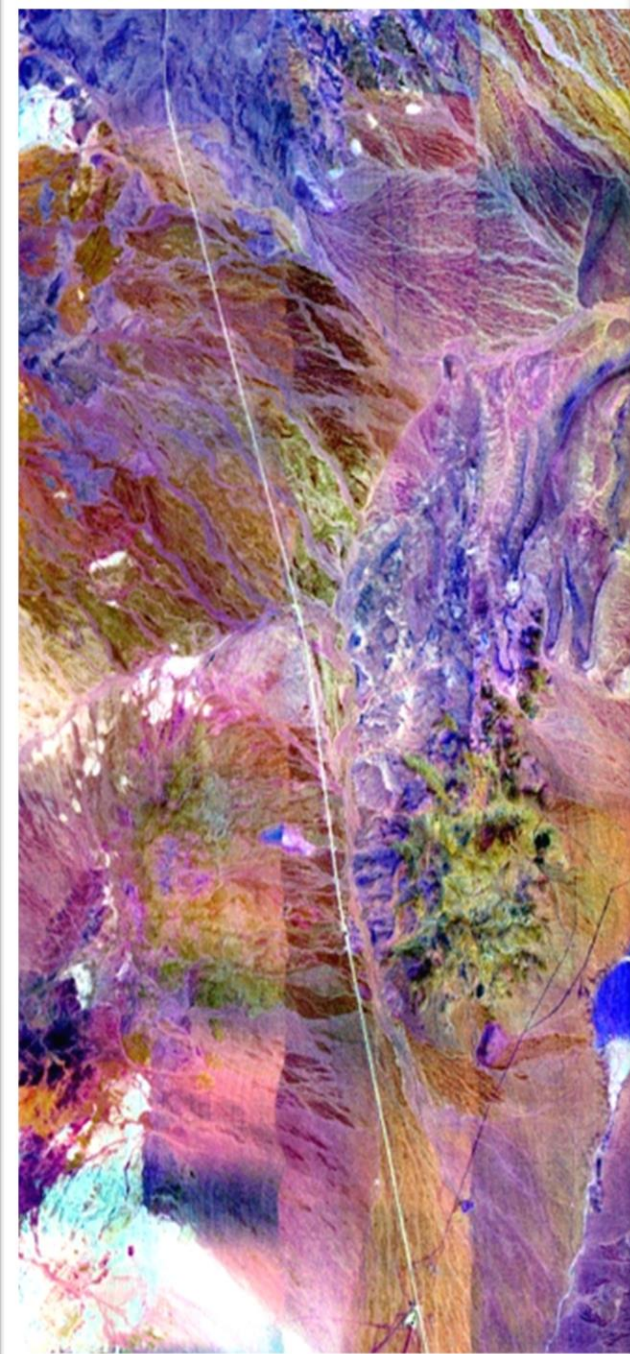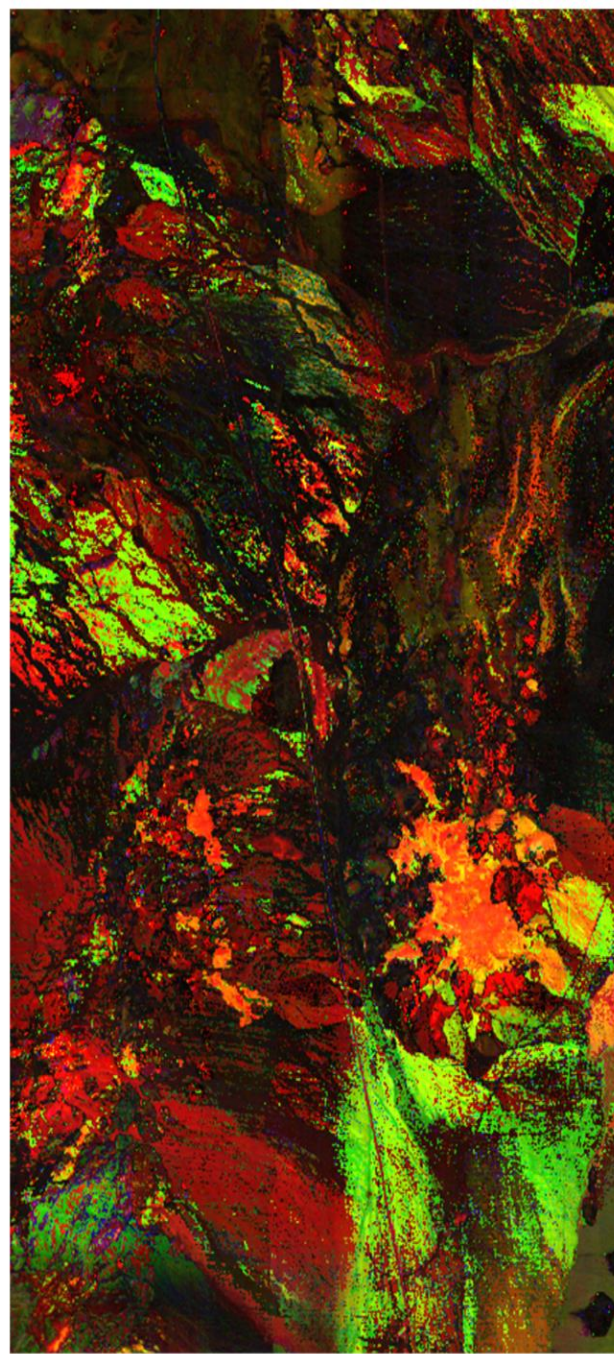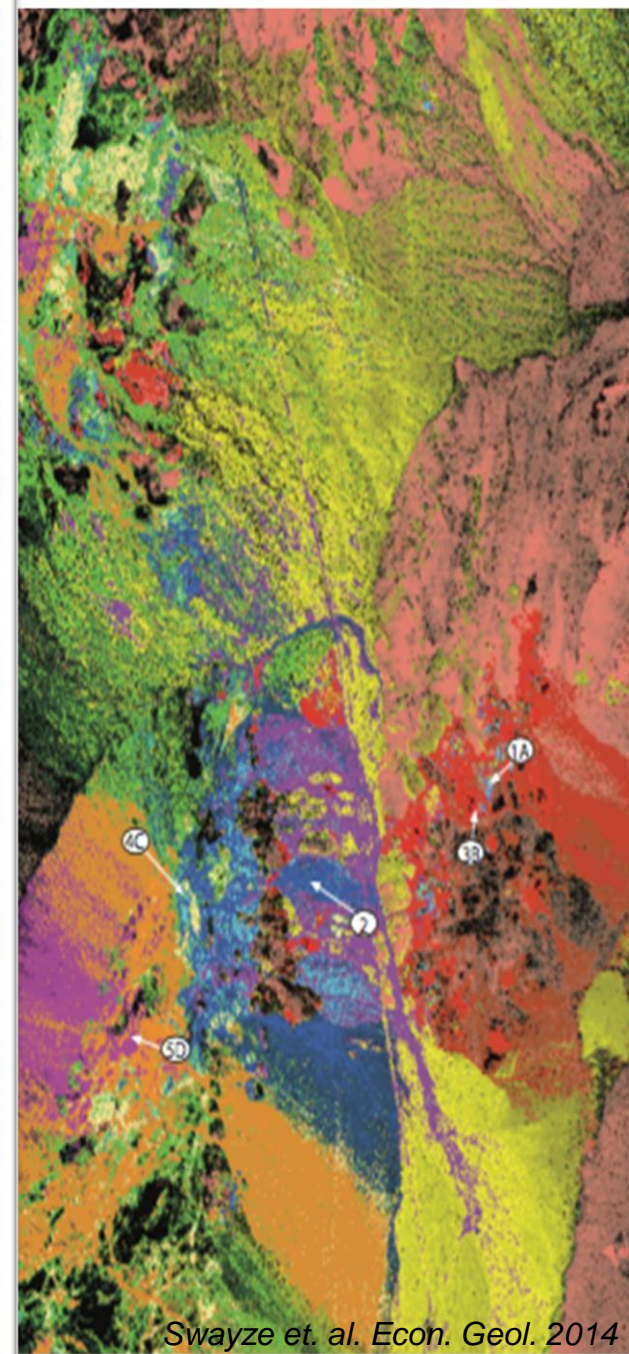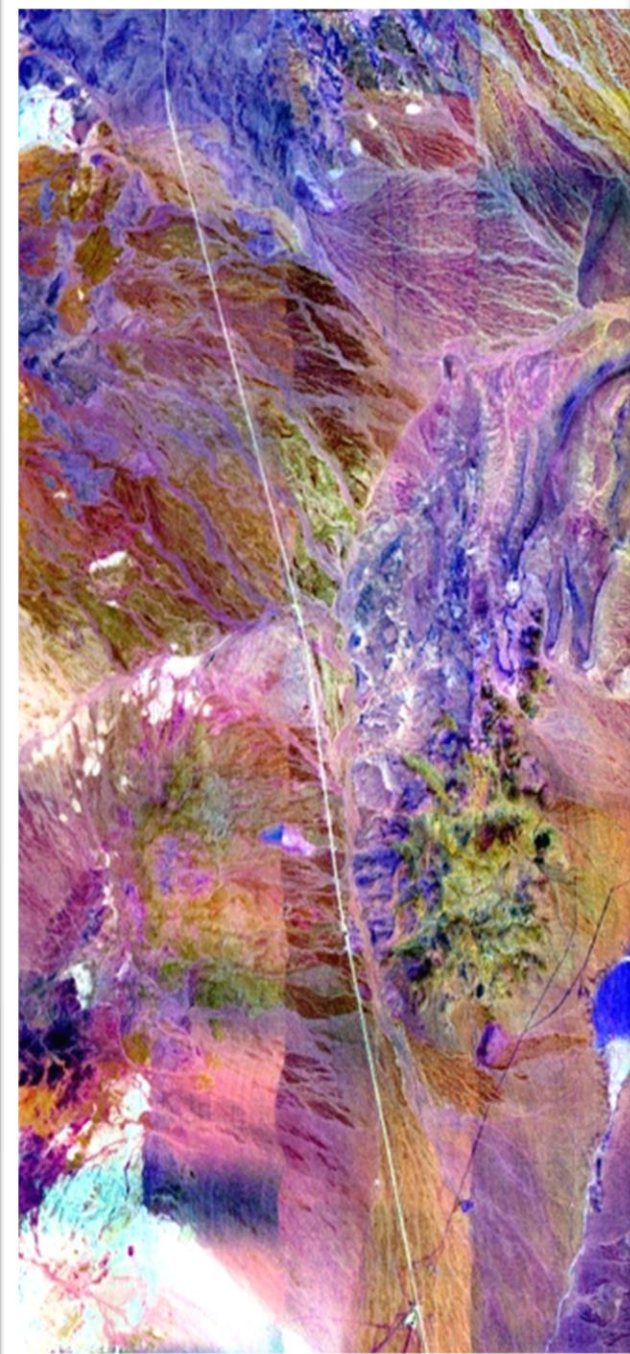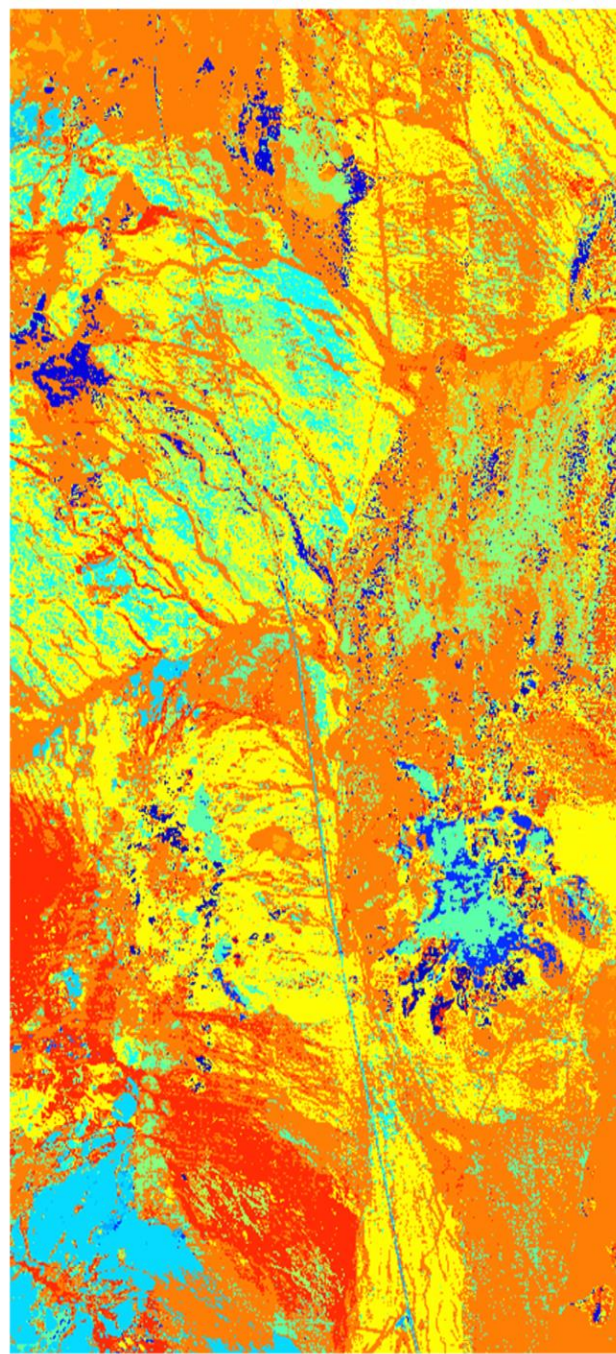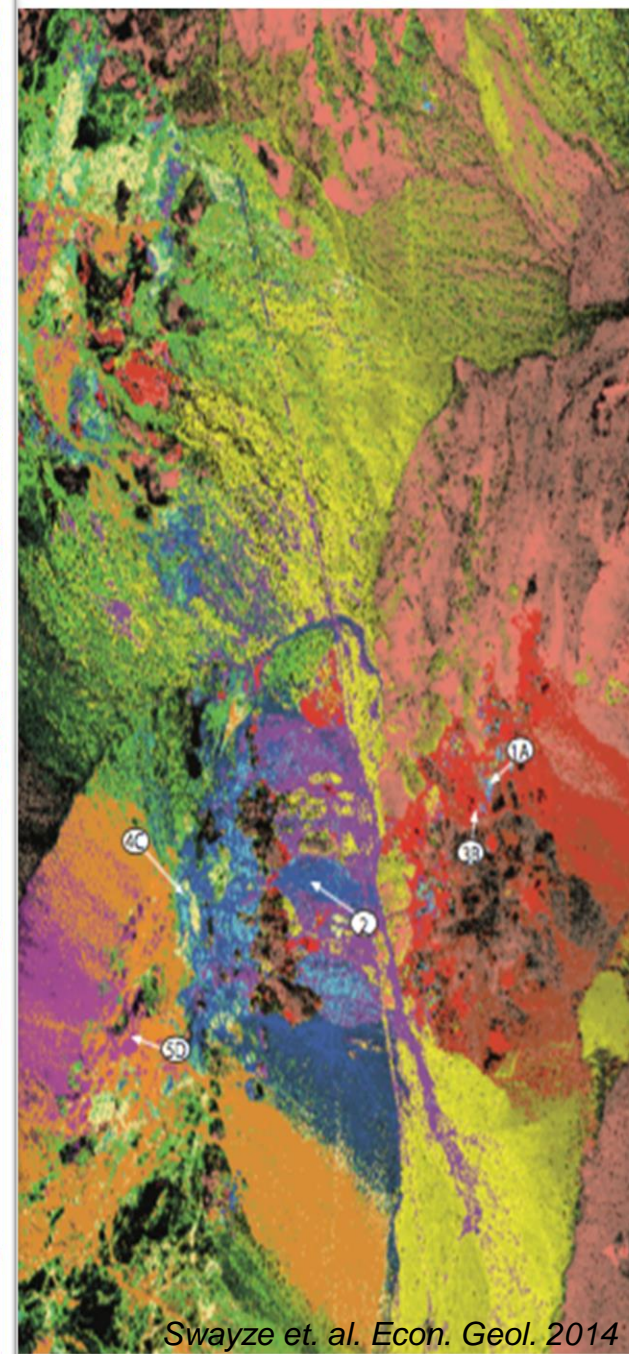
Swayze et. al. Econ. Geol. 2014

Swayze et. al. Econ. Geol. 2014

Summary

- The long-wave infrared needed to accurately map silica and feldspar minerals.
- However, it is complimentary to the short-wave infrared for mineral mapping. Ideally, an extended spectral range is needed.
- Unsupervised mineral mapping techniques show promising preliminary results when using spectral feature separation.

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